INAUGURAL ESSAY

ON THE

STRUCTURE

OF THE

MUCOUS MEMBRANE OF THE STOMACH,

SUBMITTED TO THE

Medical Faculty of the University of Edinburgh,

IN CONFORMITY WITH THE RULES FOR GRADUATION,

BY AUTHORITY OF THE

VERY REVEREND PRINCIPAL BAIRD,

AND WITH THE SANCTION OF THE

SENATUS ACADEMICUS.

BY

SPROTT BOYD,

CANDIDATE

FOR THE

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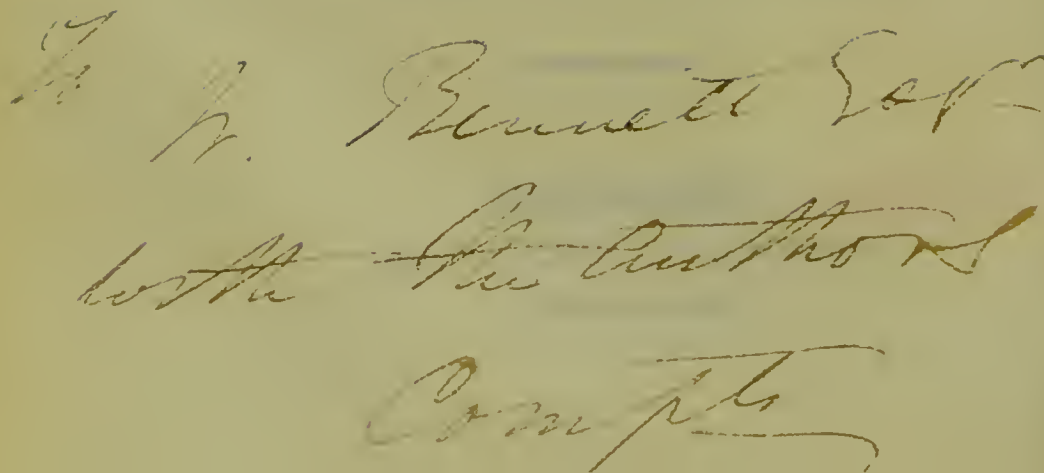

TO

JAMES SYME, Esq.

F. R. S. E.,

PROFESSOR OF CLINICAL SURGERY IN THE UNIVERSITY OF EDINBURGH;

THE AUTHOR RESPECTFULLY INSCRIBES THE FOLLOWING ESSAY,

IN GRATITUDE FOR HIS ABLE INSTRUCTIONS

AS A MASTER,

AND UNIFORM KINDNESS

AS A FRIEND.

TO

WILLIAM SHARPEY, M. D.

F. R. S. E.,

LECTURER ON ANATOMY AND PHYSIOLOGY,

THE FOLLOWING ESSAY IS DEDICATED,

AS A MARK OF RESPECT

FOR HIS SCIENTIFIC EMINENCE,

AND IN

ACKNOWLEDGMENT OF HIS KIND ASSISTANCE

IN THE PROFESSIONAL STUDIES

OF HIS FORMER PUPIL,

THE AUTHOR.

ON THE

STRUCTURE

OF THE

MUCOUS MEMBRANE OF THE STOMACH.

THE function of the mucous membrane of the stomach, though at all times a subject of interest to physiologists, is one which of late years has engaged a more than usual share of attention and research; and as an acquaintance with the structure of this membrane may be considered essential to the proper understanding of its functions, it has perhaps received from anatomists a more careful examination than any other portion of the mucous system. A reference to the labours of Bichat, Hewson, Home, Cuvier, and Billard, will show how precise as well as extensive our knowledge of the minute anatomy of the stomach had become; still, the occasional discrepancies in the statements of these authors appeared to indicate that the inquiry had not been exhausted; and though I could hope to contribute little after the investigation of the subject by so distinguished men, it seemed that a repetition of their observations would not be altogether an unprofitable task.

In the following pages I have, accordingly, endeavoured to bring together the various opinions of such physiologists as have made the mucous membrane of the stomach an object of their attention.

In the examination of these opinions, we find that there are *three* points in the anatomy of this membrane, which require separate consideration; 1*st*, Whether or not it possesses a cuticular covering; 2*d*, Its structure, whether cellular or villous; 3*d*, The glandular apparatus which it presents.

In relation to each of these points, the statements of different authors will first be brought forward, after which, a few observations, which I have myself had the opportunity of making, will be detailed.

Throughout the classes of Mammalia and Birds, the œsophagus is lined by a membrane continuous with the cuticle on the surface of the body, which is termed the epithelium. In Man this membrane apparently terminates at the cardiac orifice of the stomach; in many of the lower animals it extends much farther than this; in the pig, in the kangaroo, it is stretched over the surface of the stomach for a few inches beyond the cardia; in the horse, it completely covers the great extremity of the stomach, and terminates about the middle of the organ, by an irregularly serrated margin, its smooth white surface contrasting strongly with the reddish velvety appearance of the adjoining mucous membrane. In the Cetacea, the epithelium lines the first of the four gastric cavities found in that order of animals; in ruminating quadrupeds again, it extends throughout the first three cavities, the

fourth stomach alone possessing what may be considered a bare mucous surface.

Is this termination real or apparent? Some authors maintain that the membrane merely becomes attenuated, and is continued over the whole internal surface of the alimentary canal; and such a belief, it is said, is warranted by the similarity which exists between the mucous tissue and the external skin, both in their structure and their functions.

Cuvier, indeed, affirms the inner coat of the intestinal tube to be essentially nothing more than a reduplication of the external covering of the body. "The nervous coat of the stomach," he remarks, "continuous with the derma, the principal layer of the skin, is lined by a membrane continuous with the epidermis, thin, soft, and transparent, and as easily regenerated, when removed, as the cuticle on the surface. It is always coated with mucus, and is pierced by pores, through which that fluid escapes. In particular situations, where it is exposed to much friction, as in the gizzard of granivorous birds, this membrane becomes hard and callous." Rudolphi lends to this opinion the full weight of his authority. The true mucous membranes, he remarks, have no free sides, but are placed between other membranes, and bear to the cutis or true skin the same relation as the epithelium which covers them bears to the cuticle. He styles it indeed "the most common error of modern times," to imagine that the mucous coat is actually that which lines the intestinal canal; and lays it down as well ascertained, that the epithelium, so distinct in the œso-

phagus, is continued throughout the intestine in the form of a delicate transparent membrane.

The most powerful argument in support of this opinion is drawn from the partial developement of the cuticular layer in various animals. Rudolphi states, that he has "observed in the intestines of a badger the same laminated structure which so frequently happens in the epidermis, and Hedwig has observed the same thing in mangy dogs."

In granivorous birds a distinct epithelium lines the œsophagus. Where the gastric glands do not form a zone around the upper part of the stomach, but, as in the Ardea argala (or adjutant crane,) open into two circular spaces of very limited size, the epithelium is prolonged between these spaces, and apparently becomes incorporated with the lining membrane of the gizzard. In the majority of cases, however, where the gastric glands form their usual zone, the horny layer apparently ceases by a well-defined margin before the glands commence, and around their orifices the surface has all the appearance of a bare mucous membrane. Yet over this surface the epithelium is continued, as its remarkable developement in the gizzard fully proves; so that the mere difference in appearance does not necessarily indicate a difference in structure, and the circumstance of an epithelium not being distinctly visible in the intestinal canal of Mammalia does not preclude the idea of its existence.

It may, however, be remarked, that, often as this layer has been described, the description does not in any one instance seem to have been drawn from actual

observation; and the characters are given us, not of a membrane that has been witnessed and examined, but of a membrane such as an attenuated film of cuticle might be supposed to form. Its existence is strenuously denied by Bichat, inasmuch as it cannot be raised from the subjacent tissue by the finest instrument or most delicate dissection; boiling, maceration, which we might suppose would produce its separation, have no such effect; and blistering, so certain a means of raising the cuticle which covers the external skin, exerts no similar action on that which lines the intestine.

The argument, too, drawn from the gizzard in birds, is imperfect in some particulars. Mr Hunter observes, that the epithelium in the gizzard, and the epidermis on the surface, are attached to the structures beneath in somewhat different ways. The papillæ in the external skin arise from the derma, and enter into little cavities formed in their cuticular covering. In the gizzard this arrangement is reversed, the papillæ spring from the external surface of the horny layer, and are received into depressions in the subjacent tissue.

With such arguments on either side of the question, this point of anatomy seems at the present time to rest; nor do later writers enter into the subject, but content themselves with the simple expression of their opinion,—some, as Elliotson, affirming the epithelium to be continued throughout the alimentary canal,—others, like Billard, asserting that it terminates at the cardia

So far as simple inspection entitles us to form an opinion, the epithelium in man may be said to terminate at the lower extremity of the œsophagus, by a margin, which, though somewhat irregular, is generally well defined. This layer, which in the recent state is soft and pliable, and closely adheres to the mucous surface beneath, is rendered extremely brittle by immersion in spirits, so that the slightest transverse extension of an œsophagus that has been thus preserved, ruptures it in a hundred different directions. Its free surface exhibits a minutely papillar appearance, the papillæ scarcely projecting above the surrounding membrane, of a whitish colour, and (immediately above the cardia) arranged in irregular transverse lines. Plate I. Fig. 1. On separating the epithelium from the layer beneath, and examining it by a magnifier with transmitted light, it seems to be almost perforated by numerous small canals, corresponding in situation to the papillæ alluded to ; viewing it on an opaque ground, a similar appearance is perceived ; it is evident, however, that the membrane is not completely perforated, but merely thinner where it covers the extremity of each papilla.

On examining the surface of the epithelium which adhered to the mucous layer, the appearance is presented of openings running obliquely towards the free surface, and forming evidently the canals into which the papillæ enter. Plate I. Fig. 2.

These last mentioned bodies are minute projections from the mucous layer, ranged pretty closely to each other, each about $\frac{1}{150}$ of an inch in length, and $\frac{1}{1000}$ of

an inch in diameter, in both measurements, however, exhibiting slight variations. They are not perforated by any canal, but appear to be composed of a homogeneous cellular tissue. Plate I. Fig. 3.

In the horse, the epithelium, as Sir E. Home has shown, covers the cardiac portion of the stomach, and terminates about the middle of the organ, by a serrated margin, not being continuous with, but elevated above the adjoining mucous surface. While the membrane is attached to the subjacent structure, its surface presents a faintly papillar aspect; on gently detaching it with the handle of a scalpel, we do not, as in the human œsophagus, come at once to the surface from which the papillæ rise, but find interposed a second layer, of about the same thickness as the epithelium itself. If we examine either side of the detached portion of epithelium by transmitted light, the papillar aspect is not discernible, but the membrane appears marked by dark specks, corresponding in number and situation to the papillæ which it had covered. Plate I. Fig. 4.

The intermediate layer presents to the microscope a smooth equal surface; it is perforated by numerous foramina, about the 600th of an inch in diameter, (or perhaps a little smaller,) and having their margin slightly thickened, Plate I. Fig. 5, which, it is evident, give passage to the papillæ, with which the third or mucous surface is closely studded. These bodies are of conical form, of considerable length in proportion to their breadth, Plate I. Fig. 6; a circumstance made apparent only by a lateral view, as when looking di-

rectly down upon them they appear short and flattened. No duct or tubular structure of any kind could be detected, even by a powerful magnifier, (a lens of $\frac{1}{15}$ of an inch focus.) Their structure appeared similar to that of the papillæ in man.

The middle perforated layer, which I have just described as existing between the epithelium and the papillar membrane in the horse, appears to be analogous to that spoken of by Malpighi in his letter on the structure of the tongue. "In the larger ruminating quadrupeds," he remarks, "when the external membrane covering the tongue is removed, a glutinous substance presents itself, extended over the upper part of the tongue, white where connected with the exterior layer, dark where attached to the parts beneath. It is marked by conspicuous foramina, corresponding to the papillæ, between which innumerable small canals are visible to the microscope, varying in figure, and opening on the external surface of the tongue." Malpighi imagined that these "conspicuous foramina" naturally existed in the membrane which he described. Albinus, who repeated the observations of the Italian physiologist, formed a different opinion. He conceived that the membrane was not naturally perforated, but that it, as well as the epithelium, was extended over the surface of the papillæ. In this way, the two layers were connected most firmly, where they covered these bodies, and consequently, when the epithelium was removed, the small portion of the subjacent layer corresponding with the papillæ was detached along with it, and an aperture was left.

To determine the respective accuracy of these opinions would require a detailed and minute investigation ; meanwhile it may be remarked, that the appearance of the epithelium by transmitted light rather favours the idea of Albinus. We would naturally expect the membrane to be more translucent where it covers the extremities of the papillæ, as indeed is the case in man ; on the contrary, we find it more opaque, and this appearance could only be produced by a greater thickness of the membrane at these points than throughout the rest of its extent.

I have not been able to trace in the epithelium of any other animal a structure similar to that existing in the horse. In the pig, this membrane is considerably thicker than in the horse, and adheres much more firmly to the mucous surface beneath, so that it is almost impossible to examine the manner in which they are connected to each other.

The first three stomachs in the calf exhibit, with scarcely any modification, one kind of structure. The cavities in the first stomach, the cells in the second, the plicæ or folds in the third, are all studded with numberless papillæ, varying in size and mode of arrangement, but all presenting the same conical form. On these the epithelium is closely applied, becoming extremely thin where it covers the apex of each papilla ; nowhere is there any trace of an intermediate cribriform layer such as exists in the horse. When the epithelium is removed, the papillæ are seen formed by partial elongations of the mucous membrane. In the deer, Sir E. Home observes that each of these bodies con-

tains an excretory duct opening by three orifices at its apex. In the calf, however, there was no appearance of any similar structure.

In other animals, as the dog, cat, rabbit, the epithelium does not present any peculiarity. It is difficult to examine its structure, in consequence of its firm attachment to the subjacent membrane, which exhibits the same minute papillæ that have been already noticed.

The structure of the internal or mucous coat of the stomach presents itself as the second part of our subject. In systematic anatomical works, this membrane is commonly spoken of as exhibiting a villous surface, one, indeed, in which the villi are peculiarly prominent, and from which it derives a delicate velvety appearance. This opinion is sanctioned by high authority. "In man," Haller remarks, "and much more distinctly in some other animals, filaments or villi are perceived, projecting into the cavity of the stomach, shorter, however, than those in the intestines. The nature of these appears everywhere the same. Through them, viz. the arteries and veins, open into the gastric cavity."

According to Bichat, villi or papillæ might be detected throughout the whole mucous system. "They are found," he says, "though no doubt extremely short, in the frontal sinuses and urinary passages. On the tongue again, the intestine, the stomach, the gall-bladder, these bodies are remarkable for their length." The assertion, however, which almost immediately follows, viz. that in the stomach and intestine the

villi lie so close together, that at the first glance the membrane wears an uniform aspect, is not consistent with the idea of remarkable length ; and it appears probable, from the circumstance of the mucous surface of the gall-bladder and some other organs, which is declared to be villous by Bichat, presenting scarcely a trace of such a structure, that this celebrated anatomist was somewhat hasty in his generalization of the characters of mucous membranes.

Cuvier merely adverts to the mucous membrane of the stomach in man. " Its inner surface," he observes, " is remarkable for a number of very fine folds, which give it a velvety appearance, and which are almost wholly composed of sanguiferous vessels. In different animals, these folds of the internal membrane present varieties of size and form. Sometimes they are scarcely visible, and the surface of the intestine appears perfectly smooth ; sometimes they are scattered like little rounded granules, or like filaments, enlarged at their extremities, or tapering more or less to a point. In several animals, again, the inner surface of the intestine" (he speaks of the stomach) " instead of being marked by projecting folds of membrane, is hollowed out into numberless little depressions, as in the sturgeon and certain of the tortoise tribe ; in others, as the frog and crocodile, the surface merely exhibits slight furrowed lines, which take a serpentine course in different directions."

Billard, one of the latest authorities on the gastric mucous membrane, supports the idea of a villous arrangement. " The villosities," he says, " exist generally

over the mucous surface, and are particularly abundant towards the pylorus, where they are grouped together, slightly flattened, and separated from each other by very fine lines. In the healthy stomach, the naked eye perceives these but indistinctly; in one case, however, he remarked the folds of the membrane, which are commonly irregular, to be thrown into a lozenge form, like the reticulum in ruminating quadrupeds; while the villi were so developed, that, by passing the finger over them, they might be laid flat or raised again."

Authorities of equal weight, however, may be brought forward in support of the other opinion, that the arrangement of the mucous membrane in the stomach is not villous but cellular. The latter structure, indeed, is taken notice of by Haller, who speaks of the internal surface presenting very small rugæ, which, upon close inspection, seem to be arranged in a reticular manner, appearing to be a rudimentary form of the reticular structure, which is so beautifully displayed in the second stomach of ruminating animals. The same opinion is more distinctly affirmed by Hewson, who, though he states the whole surface of the intestinal tube to be covered by villosities, admits, that, in the large intestine, these bodies are so short, that the surface appears smooth to the naked eye, while no true villi are detected by the microscope; only, the partitions between the cells resemble villi in their structure. In the stomach a nearly identical appearance is found: "At the upper part of this organ, the villous coat appears in a microscope like a honeycomb,

or like the second stomach of ruminating animals in miniature ; that is, full of small cells, which have thin membranous partitions. Towards the pylorus, these partitions are lengthened, so as to approach to the shape of the villi in the jejunum."

Fordyce was led by his researches to believe that the stomach, strictly speaking, possessed no true internal membrane. The mucous layer and submucous cellular tissue he conceived to form but one structure, which, loose externally, where it was attached to the muscular fibres, became more and more condensed towards its internal surface, till it was able to retain the aliment which the stomach received. On the surface of the stomach, " the laminæ of this cellular tissue might be perceived crossing one another so as to form a number of irregular cells. The surfaces of each of these membranes were covered again by finer and smaller membranes, again crossing one another, so as to form lesser and shallower cells, which very much increased the interior surface." On microscopic investigation, he, without good reason, placed little reliance. The objection, that in different lights different appearances are apt to present themselves, again varying according to the degree of moisture of the mucous membrane, is no more to be urged against examination by the microscope than against that by the naked eye ; and optical deceptions are little likely to occur, unless the magnifier be of much higher power than what is required for minute inspection of the mucous surface.

We owe to Sir E. Home the most minute descrip-

tion of the cells alluded to. He states, that " they are found in the form of a honeycomb in the upper arch of the stomach, and are of greatest depth in this situation, though seen all over the cardiac portion of the organ, but so faint that a high magnifying power is required to render them visible. In the pyloric portion, the same cellular appearance continues ; but here and there are small clusters, the sides of which rise above the surface, giving the appearance of foliated membranes."

In describing the stomach of the Cetacea, Cuvier makes mention of a structure in the second and fourth gastric cavities, which he does not appear to have remarked in any other animals. " The internal membrane of the second stomach," he says, " is in great measure composed of fibres, perpendicular to the two surfaces, placed very close together, which perhaps are of a glandular nature. These fibres exist equally in the internal membrane of the fourth stomach, but in that of the third no similar appearance can be traced." This observation of Cuvier's has been repeated with regard to the second stomach of the porpoise by Dr Knox, who conjectured that the fibres might exercise electric phenomena, as connected with the process of digestion. On examining this structure by the microscope Dr Brewster ascertained the fibres to be minute tubes, while the internal membrane appeared covered with hollows or depressions, corresponding with their extremities.

I have already described the structure of the epithelium, down to where it seems to terminate at the car-

diac orifice of the stomach. So soon as the line of demarcation is passed, a very different aspect is presented. In some cases the mucous membrane exhibits a loose flocculent appearance, without any well defined structure. This may perhaps be referable to post-mortem changes. In other cases, again, where post-mortem alterations cannot be remarked, an irregular honey-comb appearance of the mucous membrane is observed, the cells being of considerable size, about $\frac{1}{80}$ or so of an inch in diameter. Very soon, however, not half an inch from the cardia, these give place to the small regular cells, which may be said to characterize the whole of the inner surface of the organ. The appearance of these cells, throughout the cardiac portion of the stomach, corresponds to the representation given of them by Sir E. Home. When the mucous membrane is extended, they appear tolerably regular both in form and size, varying from $\frac{1}{200}$ to $\frac{1}{350}$ of an inch in diameter, being smaller in the young than in the adult subject. Towards the pylorus, the mucous membrane, which is thin throughout the great cul de sac of the stomach, becomes considerably thicker, the dimensions of the cells are increased, and an appearance somewhat resembling that described by Sir E. Home is perceptible. He mentions the patches distinguished by the foliated membranes as existing particularly towards the pylorus. They may be found, however, in the cardiac portion of the stomach likewise; perhaps not actually at the great extremity, but certainly opposite the termination of the œsophagus. In the engraving given by

Home of these patches, the wall of each cell is represented as rising above the general surface of the stomach, and being cleft into a number, ten or a dozen, of rounded segments, which form a complete fringe about the mouth of the cell. These projections of the mucous membrane are, so far as I have been able to observe, much less numerous. There is no regular fringe, but here and there a prolongation of membrane, resembling an ordinary villus of the intestine, rises from the partition between two cells. Plate I. Fig. 7. These bodies, from their small size, are not easily distinguished: they give to the surface a more flocculent and velvety appearance than is presented by other parts of the stomach. The cells near the pylorus are in some cases about $\frac{1}{100}$ of an inch in diameter; and on examining them on a dark ground, and with the aid of a reflector and a magnifier of $\frac{1}{4}$ of an inch focus, their interior is pretty distinctly seen, presenting an appearance similar to what I have presently to describe as existing in the stomach of the pig, when it is more clearly visible, and more easily examined. The floor of each cell appears perforated by numerous circular openings, as if a number of tubes opened on it, Plate I. Fig. 8; and on making a vertical section of the mucous membrane, it is seen to be composed of striæ or fibres running perpendicularly from the free surface of the membrane to the cellular coat beneath.

These fibres appear, partly from direct observation, partly from the analogy of a similar structure in the pig, to be small tubes lying parallel to each other; one extremity of which is shut and attached to the

submucous cellular layer, while the other opens on the free surface of the mucous membrane itself. In the majority of instances, the cardiac part of the stomach exhibits a closely similar structure; sometimes, however, where the mucous membrane is very thin, a different appearance is perceived. The surface under the magnifier displaysno regular honeycombstructure, but is thrown into small folds, analogous to the villi in the duodenum, which present an infinite variety of form. Some have a broad attachment to the surface of the stomach, and project but slightly into its cavity; others again, from being much elongated, closely resemble the villi of the duodenum; some run in a straight line, others take a circular course, and form a cell, or half a cell, or a series of cells gradually passing into the perfect honeycomb structure. Plate II. Fig. 1. Uniformly scattered over the membrane between these folds, the little tubes I have alluded to are seen. Towards the pylorus these are long, ranged closely together, and open into the cells; here again they are extremely short, little more than simple rings lying on the membrane, and they are not set close together, but open separately and primarily on the mucous surface. Plate II. Fig. 1. They are about $\frac{1}{600}$ of an inch in diameter, appear to have no immediate connection with the cells, into which they generally open, and possibly are subservient to a different function.

In the pig, the surface of the mucous membrane exhibits to the naked eye considerable differences in appearance. Throughout the cardiac portion of the stomach, it is of a greyish hue, and is marked by nume-

rous small sulci of tortuous form, which, together with the corresponding elevations between them, give the membrane somewhat of a glandular aspect. About the middle of the stomach on the greater curvature, the furrows become larger and deeper, dividing the membrane into larger compartments, while the surface has a pinkish red colour, and has more of a flocculent appearance than towards the cardia. Near the pylorus the furrows almost disappear, and the surface is comparatively smooth and regular. These sulci are not incidental folds of the mucous coat, for no distension of the stomach produces their obliteration; the honeycomb structure exists throughout, the cells being considerably larger than those in man, and visible on close inspection even to the naked eye. In the cardiac portion the walls of the cells are smooth and regular, Plate II. Fig. 2; near the pylorus, they are fringed with partial prolongations of the mucous membrane.

The lining membrane of the stomach throughout, and particularly towards the pylorus, is of remarkable thickness, and at the same time of firm consistence. Making a vertical section with the knife, or, what is better, scratching it through, it appears composed of slender parallel fibres, each about $\frac{1}{300}$ of an inch in diameter, closely arranged together, running perpendicularly from the surface to the cellular tissue beneath. Plate II. Fig. 3. Removing the surface of the mucous membrane by a horizontal section, the cut surfaces of these fibres present themselves, showing their cylindrical form. Again slicing off a thin layer, and viewing it under

the microscope by transmitted light, the section of each cylinder exhibits the appearance of a ring, indicating its having formed a part of a tube ; and, placing a small portion of the mucous membrane on an opaque ground, and using reflected light, the mouths of these tubes can be distinctly perceived within the cells ; a variable number of tubes, 2, 3, 4, opening into each cell according to the form and size of the latter. Plate II. Fig. 4. Where they are attached to the cellular coat of the stomach, they terminate by shut extremities amid a close plexus of capillaries, from which vessels arise, and, running parallel to the tubes in the cellular tissue which unites them, ramify minutely on their surface. Plate II. Fig. 5. The injection is apt to force its way into the tubes, which then appear of a somewhat conical form, Fig. 5, tapering slightly as they approach the free surface of the membrane.

In the horse, where the epithelium terminates, the mucous membrane at the first glance wears a villous aspect even under the magnifier. On close inspection, however, the reticular structure becomes evident, similar to, though fully more minute than, that which we find in man. Proceeding along the surface towards the pylorus, the same arrangement is perceived, becoming more and more combined with the villous structure ; the walls of the cells are prolonged, and float loosely in the water, under which it is necessary to examine them, and their orifices consequently are manifest only in particular points of view. A perpendicular section of the membrane displays the tubular structure, which is here extremely soft and delicate. I could perceive

the extremities of the tubes at the bottom of the cells, but not very distinctly, partly from the small size of the latter cavities, partly from the way in which they are obscured by the surrounding villi.

The honeycomb appearance in the fourth stomach of the calf, though very minute, the cells being not above $\frac{1}{300}$ of an inch in diameter, is yet extremely distinct. The mucous membrane, compared with that of the pig, is thin ; the tubular structure, however, is perceptible, as indicated by the fibrous appearance which a section of the membrane presents ; although, owing to the small size of the tubes, their openings into the cells could not be distinguished.

The appearances in the stomach of the sheep closely resemble those just mentioned ; the tubular structure is fully more distinct, each tube being somewhat more than $\frac{1}{1000}$ of an inch in diameter. By transmitted light they appeared of a reddish yellow hue ; some seemed empty ; in others, the contents appeared as if coagulated by the spirits in which they had been preserved ; and under a high magnifying power, (120 diameters,) the thickness of their walls could be distinctly observed, as marked by two parallel lines running close to each other, and forming a shut sac at the extremity farthest from the mucous surface.

The structure of the inner membrane in the dog and cat appeared precisely the same. The honeycomb appearance is in both well marked ; the tubular structure is observable in both, particularly towards the pylorus, where in the dog the tubes are seen to terminate in the cells.

The mucous membrane in the rabbit is somewhat different. After repeated examination, I concluded that it resembled the stomach of the horse in presenting a combination of cellular and villous structure, such as Sir E. Home described in the patches of the stomach in man. On later inspection, however, I could not discern in the cardiac portion any cellular structure; the surface appeared studded with close set cylindrical papillæ, in which an internal cavity could not be satisfactorily perceived, but which I believe to be a tubular structure, resembling that which has been noticed as existing in the cardiac portion of the human stomach.

In the hedgehog, on extending a part of the cardiac end of the stomach, most frequently no cellular structure can be perceived, and a crowded assemblage of small white papillæ is alone visible. In particular lights, however, a cellular structure is seen to exist, appearing stretched like a fine net-work over the upper surface of the papillæ. The partitions between the cells are extremely thin, and send out slender filaments, which near the pylorus float over and obscure the cells themselves.

In the mole, the pyloric portion of the stomach exhibited the honeycomb structure, well marked, though minute. In the cardiac portion it was less distinct; but the more flocculent aspect of the surface might be attributed to the action of the gastric juice before the stomach was opened. The duodenum also was cellular, but the cells were very different from those of the stomach. In the stomach they were uniform in

size, and regular in shape; in the duodenum they were of all shapes and sizes, the larger cells being redivided into smaller compartments.

In the second stomach of the porpoise, the tubes are about $\frac{1}{10}$ of an inch in length, and are easily seen. The cells on the surface of the inner membrane are extremely small, so much so, that each, as Dr Brewster believes, is probably the orifice of a single tube. In the third cavity, the honeycomb structure is very distinct, but the tubes are wanting, and the membrane is directly applied on the cellular tissue beneath.

In the fourth stomach, again, the appearances are precisely similar to those found in the second; the tubes are considerably shorter, but their diameter and mode of termination at the surface are the same.

The stomach of the turtle consists of two portions, separated from each other by a slight constriction. In both, the muscular parietes are of considerable thickness, particularly in the second; though the difference between the two is by no means so marked, as that the latter should be entitled to the name of gizzard, which Sir E. Home has bestowed upon it. In the first portion the inner surface has a rough flocculent appearance, without any well defined structure; in the second, the membrane is thrown into longitudinal folds, and exhibits the honeycomb arrangement very distinctly.

The mucous membrane of the stomach in the water-newt, when examined immediately after death, appeared disposed in thin irregular folds, running in various directions, and presenting neither cells nor

villi. The stomach was extended, and placed in spirits, and in a day or two was again examined; it appeared a good deal changed. In the cardiac portion the indistinct flocculent surface and prominent longitudinal folds were alone visible; the pyloric portion exhibited the honeycomb structure in as well-marked a manner as any of the Mammalia. The cells were of round or oval form, about $\frac{1}{300}$ of an inch in diameter; and the mucous membrane was extremely thin, so that it was scarcely possible that any tubular structure could have existed beneath.

In the frog, the stomach, when examined immediately after death, presented no cell or prominence of any kind, but a smooth unvarying surface. After preservation in spirits, it exhibited numerous longitudinal waving ridges, running side by side to the pylorus, where the structure changed, and the mucous membrane was disposed in loose transverse folds.

The œsophagus in the haddock is lined by a shining bluish membrane, along which are ranged thin translucent folds, sending off slender prolongations, which hang loose in the cavity of the œsophagus. In the cardiac part of the stomach, the mucous lining is thrown into loose irregular cells, which in the pyloric portion become more compact, and assume a perfect honeycomb appearance. In the duodenum, however, and pyloric appendages, the cells are equally distinct.

In the whiting, throughout the whole surface of the stomach, the honeycomb structure is most distinct, except in the immediate neighbourhood of the pylorus, where the cells almost disappear, and the lin-

ing membrane is arranged in folds converging to the pyloric orifice. A slight constriction marks the opening into the intestine, on which the folds are a little way prolonged, when the cellular structure again shows itself, and is continued into the pyloric appendages.

In the common flounder, the traces of honeycomb structure were indistinct, the mucous membrane being thrown into longitudinal folds. Nor was there in the duodenum any cellular arrangement; but an extensive surface was presented by numerous duplications of the lining membrane, running along the intestine, with their free margin floating loosely in its cavity. As they recede from the pylorus, the number of these folds gradually diminishes. They probably supply the place of pyloric appendages, which in this fish are wanting.

In another species of flounder, the inner coat of the stomach displayed no cellular structure of any kind. To the naked eye it appeared perfectly smooth, and the microscope detected only very minute papillæ sprinkled over its surface. The duodenum possessed the folds already described.

Lastly, I turn to the third part of my subject, and inquire what glandular apparatus has been described by authors as existing in the gastric mucous membrane. In the human stomach, Haller remarked, such a structure could not be distinctly traced. Pores, however, might be seen in all parts of the organ, from which a mucous fluid issued upon the internal surface; and once or twice he had witnessed lenticular glands

situated in the submucous tissue. Of the existence of these latter bodies he seems confident; and adds, that "they should not be rejected, because they cannot be always shown."

Two sets of glands are generally described as being present in the alimentary canal; the agminatæ, or glands of Peyer, the solitariæ, or those of Brunner. The former exist only towards the lower part of the ileum; the latter are scattered over the intestinal tube, and are found alike in the colon, the small intestine, and the stomach. It is to these last that Haller, in speaking of the lenticular glands, and referring, as he does, to Brunner's writings, probably alludes. By the majority of authors who have described the solitary glands, as Cuvier, Bichat, Billard, Elliotson, they are looked on merely as muciparous crypts, situated in greatest numbers around the pylorus, where in the kangaroo and cat tribe, they, according to Cuvier, form a separate glandular tunic of the stomach. The glands which Sir E. Home has represented as the secreting organs of the gastric fluid in man and several Mammalia, are placed in a different locality, being clustered around the cardia. In the human stomach, we learn from him, no pyloric glands exist, while the cardiac glands are tolerably distinct, though by no means so well marked as in the lynx and a number of carnivorous quadrupeds. Rudolphi, again, speaks of the pyloric glands, as being nearly a constant appearance in the stomach of man. "The glands of the stomach," he says, "show themselves in two places, *first*, at the cardiac orifice, where a number of them are scattered round the

commencement of the organ ; *secondly*, in the pyloric half of the viscus, which is almost entirely covered with glands. In the first situation they lie more superficially, and are seen when the muscular tunic is removed; in the second they lie much deeper in the substance of the proper membrane, as in the gullet." In the water-rat, the gastric glands are depicted by Sir Everard around the pylorus ; in the hare they are shown on the great curvature ; in the ass they exist on the smaller curvature ; in the horse, they could not be seen, owing, Sir Everard seems to think, to the less delicate structure of the organ, though, he observes, there can be no doubt of their existence. In the elephant the gastric glands were not perceptible ; in the kangaroo they were found arranged in clusters somewhat resembling the Peyerian glands, which run in three rows along the pyloric half of the stomach. In the Ornithorynchus hystrix, a glandular structure surrounds the pylorus, the excretory ducts of which appear to be formed in a number of horny papillæ that project into the cavity of the stomach, and which, in Sir Everard's delineation, resemble the firm, pointed processes found in the œsophagus of the turtle.

So far as I have myself observed, the traces of glandular structure, which present themselves in the examination of the human stomach, are extremely various ; occurring in some cases near the cardia, in others towards the pylorus. In a third class, a careful survey detects merely an uniform appearance of the mucous membrane, without the slightest indication of glands. Below the termination of the epithe-

lium at the cardia, the mucous membrane may in many cases be seen elevated by small oval or globular bodies, lying in the submucous tissue, seemingly of glandular nature, but not opening by any distinguishable orifice on the surface of the stomach. Near these there commonly lies a flattened yellowish mass of variable extent, scarcely if at all projecting above the mucous surface, and marked by distinct depressions or foramina. Sometimes it exists in small separate patches, none of which are at any distance from the cardia; its appearance is decidedly glandular.

In what may be termed the body of the stomach, any well defined glandular structure is but seldom found. On the summit of the folds which run irregularly along the surface of the organ, round or oval fossæ may occasionally be observed, in all probability mucous crypts. Towards the pylorus, the glandular structure is generally better marked, and, in some cases, is exceedingly distinct. Plate II. Fig. 6. exhibits the pyloric glands in a state of very perfect developement. It is taken from a stomach in the possession of my friends Dr Sharpey and Dr A. Thomson, which, throughout the greater part of its surface, presents nothing remarkable, but is perhaps more than usually disposed in irregular folds. About $3\frac{1}{2}$ inches from the pylorus these disappear, and the surface then displays a crowded assemblage of small eminences, each about $\frac{1}{6}$ of an inch in diameter, and marked in the centre by an orifice distinct to the naked eye. Some glandular appearances are also visible around the cardia. The stomach was taken from a young

girl, who died suddenly while apparently in a state of perfect health.

In the pig, a few elevations resembling glands may be perceived, scattered here and there over the mucous surface. When best marked, they have a circular form, and the central orifice appears radiated, a circumstance observable also in the glands of the human stomach, mentioned above. Their central cavity is easily examined, and is found to exhibit the same honeycomb structure as the rest of the lining membrane. In the fourth stomach of the sheep, towards its superior orifice, oval glandular bodies visible to the naked eye are sometimes sprinkled. In the horse and calf I have not been able to distinguish any unequivocal glandular appearance. The same remark applies to the dog, in which animal I have several times examined the stomach taken from the body immediately after death, and while the process of digestion was going on. In one instance, in a cat, on applying the glass to the lesser curvature of the stomach, I was struck by observing small round elevations, crowded together, which had all the appearance of glands, and in the centre of some I even imagined that I perceived an orifice. Their situation corresponded exactly to that assigned to the gastric glands by Sir E. Home, and they appeared dark-coloured, as if congested with blood, (the animal was killed while digestion was going on,) it turned out, however, that the appearance was produced by small masses of mucus, for, on lightly applying the handle of the scalpel, they were all swept away, and the membrane beneath presented itself with the usual honeycomb structure.

It now remains to speak briefly of the bulbus glandulosus, the proventriculus, or true stomach of birds. It is generally admitted, that, from the glands which open into this cavity, the gastric fluid is secreted, and it therefore becomes important carefully to examine the structure of these organs, as from it we may fairly draw analogical inferences with respect to the structure which in the class of Mammalia performs a similar function.

Sir E. Home, the only author who notices in detail this part of comparative anatomy, dwells at greater length on the inner membrane of the gizzard, and the external form of the gastric glands, than on the internal structure of these latter organs. "In birds of prey," he remarks, "the glands have the same relative situation as in carnivorous quadrupeds;" an expression, which, coupled with another respecting the little awk, in which he observes, that "the termination of the œsophagus is only known by the ending of the cuticular lining, and beginning of the gastric glands," is somewhat opposed to his repeated assertion, that the proventriculus is merely a portion of the œsophagus; and also to his latest conclusion, founded on this assumption, viz. that in man the secreting organ of the gastric fluid is placed in the œsophagus. "The glands," he continues, "in carnivorous birds are placed at right angles to the membrane lining the proventriculus, through which are openings for excretory ducts. Their internal surface is villous."

In the common fowl, the inner surface of the glands (Sir Everard states) has a pulpy appearance. In the

swan it presents a carunculated rather than a villous aspect.

A good deal has been written by the same author about the internal surface of the gizzard. Still, the question is undecided, whether this portion of the stomach is in all birds lined by a cuticular expansion; whether the varieties in its internal appearance result merely from different degrees of developement of a structure which always exists; or whether the horny layer is peculiar to some families, while in others, and in particular the purely carnivorous tribes, the lining membrane is of a strictly mucous nature. It is more easy to imagine the same essential structure existing in all, and merely modified in particular instances, than to admit a primary difference in the formation of so important an organ to occur in birds, the nature and habits of which are closely similar. For the horny layer is by no means peculiar to those birds in which trituration is essentially necessary for the digestion of their food. "In the pelican and solan goose," Sir Everard remarks, "the internal surface of the gizzard is soft and villous." In the sea-gull, again, the habits of which are similar to those of the gannet, the cuticular lining is thick and hard, and the digastric muscle is strong. In the flamingo and the sea parrot the same structure exists. In the bustard, probably a carnivorous bird, while the digastric muscle is thin, the cuticular layer is thick; in the Ardea argala or adjutant, and in the crow, which feeds on grubs and carrion, the horny layer is also well developed.

To return to my description of the glandular part of the stomach. In the common fowl, the slightly

elevated orifices of the gastric glands are sufficiently distinct. Around them, from where the epithelium terminates to where the gizzard begins, the mucous membrane is arranged in transverse folds, which run in waving lines between the openings of the glands. These again are connected by little membranous partitions, which pass from one fold to the other, and give the whole an irregular cellular appearance. As we approach the gizzard, the margins of these folds send out villous prolongations, which become more and more numerous, presenting a structure analogous to that found in man and other animals towards the pylorus. The inner surface of the gastric glands exhibits a well-marked cellular structure, though the cells are not regular in shape, nor uniform in size; while a section of the wall of a gland displays a fibrous structure, such as is seen in the mucous layer of the stomach in man, the pig, &c. though on a smaller scale.

At the upper part of the proventriculus in the curlew, the lining membrane has a distinct honeycomb appearance, which continues between the orifices of the gastric glands. In the latter situation the cells become coarser, their walls are thicker, (a change more and more manifest as we approach the gizzard,) and their form less regular. The glands are simple hollow cylinders, which internally do not present the cellular appearance that might have been anticipated, but rather seem studded with very minute papillæ, in the centre of each of which there is an exceedingly minute aperture, barely perceptible when magni-

fied 32 diameters. The perpendicular tubes are clearly seen on making a section of the gland; and the appearance of papillæ perhaps arises from these bodies opening separately into the cavity of the gland by slightly projecting orifices.

The form of the glands in the water-hen resembled that in the curlew. Each was about $\frac{1}{8}$ of an inch in length, and their mouths, which were closely placed together, could, from their small size, scarcely be distinguished. Within, the surface did not possess the usual honeycomb structure, but presented orifices like those of the tubes in the stomach of the pig, of a round or oval form. Plate II. Fig. 7.

Between the mouths of the gastric glands in the goose, the surface is traversed by membranous ridges similar to those in the fowl. Each gland is described by Sir E. Home as being composed of several short tubes, closed at one extremity, and opening by the other into a common duct. In the turkey and fowl such a structure exists, but in the goose each gastric gland appears a simple hollow cylinder, opening by a small aperture into the general gastric cavity. The internal surface has a cellular structure, Plate II. Fig. 8; the cells so small that I could not discern in them the mouths of any tubes; though that such mouths existed, I have no doubt from the striated appearance, Fig. 8, presented by a section of a gland. The structure of the glands in the turkey resembles that of the glands in the fowl so closely that a separate description is unnecessary. Both the cellular and tubular structures are exceedingly distinct.

From observations so limited as these, we obviously cannot venture to draw any positive conclusion as to the source of the gastric fluid. Before we can determine this with certainty, much patient investigation, and an extensive comparison of the structure of the stomach in different animals, will be required; and, on the preceding pages, we can only found speculations to be confirmed or refuted by after research. From the circumstance of an apparatus existing in birds, the function of which was universally admitted to be the secretion of the gastric juice, it seemed but a fair inference to suppose that in Mammalia likewise a structure should be set apart for the performance of so important an office; and, since in the stomach of man and other animals glands do exist, the majority of authors, whether relying on their own observations or those of their predecessors, have expressed the belief, that in these glands the solvent liquid is formed. Where do the gastric glands present themselves? is, however, a question to which many different answers have been returned; and the very circumstance of their being by one author referred to the œsophagus, by another, placed near the pylorus, or, it may be, towards the cardia, is certainly not easily reconcilable with the idea of their secreting a fluid essential to the process of digestion.

They have been said by Sir E. Home to exist in the œsophagus,—an assertion founded on the erroneous assumption, that in birds the glandular portion of the stomach is but a part of the œsophagus. The lacunæ, which in man are scattered over the internal surface

of this tube, are represented as the gastric glands; while the similar lacunæ, which equally exist in birds, and which might with as good reason be supposed to pour out the solvent liquid, are quite forgotten.

Sir Everard's reasoning on the subject is unsatisfactory, for nothing could be more improbable than that the gastric juice should be formed out of the organ where its action is required. If, in ruminating quadrupeds, it were secreted in the œsophagus, the first, not the fourth stomach, would be the seat of the process of digestion.

At another period, it was maintained by the same anatomist, that in Man and several of the class Mammalia, the gastric juice was effused by the cardiac glands, and the action of this fluid after death, in operating chiefly on the great arch of the stomach, opposite the entrance of the œsophagus, was brought forward in support of the idea; but as at that part of the stomach the mucous membrane is thinnest, and at the same time the most dependent after death, it follows that it in particular would be acted on by the gastric fluid, from whatever source that was derived.

In the human stomach Sir Everard saw no pyloric glands. Other observers have mentioned these alone. Do the pyloric glands then secrete the gastric juice? The variety in appearance which they exhibit is opposed to such a belief. In many cases altogether absent, or at all events invisible; in some, scattered here and there over the mucous surface; in a few existing in considerable numbers,—is this compatible with the idea of their pouring out a secretion, of which the

wants of the system require an uniform and never-failing supply? They are probably merely the glands of Brunner, which are well known to be extremely variable in number and appearance. They are the isolated glands described by Billard, found chiefly in the pyloric portion of the stomach; the mucous follicles mentioned by Cuvier as existing between the larger folds of the mucous membrane, and the orifices of which are more distinct towards the pylorus; the muciparous crypts, of which Elliotson speaks as the secreting organs of the mucus which covers the surface of the stomach, and which, he says, are clearly perceived about the pylorus.

It is only in the beaver, the wombat, and the manati, which possess a glandular structure peculiar to themselves, that there appears to be any organ set apart for the gastric secretion. And, even in their case, we have no positive evidence on the subject. Sir E. Home has shown that in the beaver, the glandular structure closely resembles that of the gastric glands in certain birds, so far as the arrangement of the mucous membrane is concerned; but it is probable that Cuvier would not have termed the secretion of this gland a mucilaginous fluid, nor have stated that the fluid poured out by a similar organ in the Manatus borealis resembled the secretion of the pancreas, if he had imagined that these structures were destined to secrete the solvent liquor.

In support of the opinion, that the gastric juice is effused by the general mucous surface of the stomach, it may be stated that such was the belief of Bichat,

who imagined that the mucus of the stomach was secreted by the inner membrane, while the gastric juice was exhaled. Tiedemann and Gmelin, in their work on digestion, speak of no gastric glands, but mention an afflux of blood to the mucous membrane, followed by an increased secretion of the solvent acid liquor. Dr Elliotson states that the cardiac portion of the stomach is the chief seat of digestion; it is this which is found half-digested after death, and its contents are more fluid than those of the pyloric portion. He quotes also a case from Dr Philip, in which the aliment was well digested up to the day of the individual's death, in which the whole internal surface of the stomach, with the exception of its cardiac extremity, was found in a state of ulceration.

It is, however, improbable that a simple mucous expansion should perform a double office, and separate from the blood both its own mucus and the gastric juice; nor does the cellular honeycomb structure, which exists in the stomachs of so many animals, seem in any way connected with the latter secretion, inasmuch as it is not peculiar to the stomach, but occurs in other situations, in the duodenum, the colon, the gall-bladder. But if in the stomach, and in it alone, we can trace a structure essentially different from simple mucous membrane, and which, therefore, we cannot suppose to be concerned merely in mucous secretion, we may be allowed to suppose that some relation subsists between such a structure and the peculiar office of the organ in which it is found. It is possible that in the minute tubes, of which

the internal layer of the stomach seems in many animals to be in great measure composed, the gastric fluid may be formed; and the conjecture is strengthened by the circumstance, that a similar formation may be traced in the gastric glands in birds, the peculiar office of which is universally admitted to be the secretion of the solvent liquor. But we are not entitled to anticipate a similar structure as we descend through the still lower classes of animals. The relation which exists between the stomach and the general system is not the same throughout, and the structure of the organ will differ in a corresponding degree. "In proportion," Dr Roget remarks, "as we descend in the scale, we find the assimilatory process more and more simplified by the concentration of organs, and the union of many offices in a single organ; till we arrive in the very lowest orders, at little more than a digestive cavity, performing at once the functions of the stomach and of the heart, without any distinct circulation of nutrient juices, without vessels, nay, without any apparent blood." Where the functions of the stomach are so complex, it may well be supposed to have a structure differing from that which it possesses when devoted to the single purpose of digestion.

If the tubular formation be not connected with the secretion of the gastric juice, the query, where is this fluid separated? still remains, more difficult perhaps of solution, but not less interesting than before; while another object of inquiry is presented; to determine, viz. what is the office of the structure in question. The mere fact of its existence is all that I have at-

tempted to show; believing that no observation in physiology, however trifling, is altogether destitute of value; and this, though unimportant when considered singly, may perhaps assist in the elucidation of a subject confessedly obscure, when connected with observations that physiologists have already made, and those that within a few years more will probably be given to the world.

EXPLANATION OF THE PLATES

PLATE I.

Fig. 1. Portion of epithelium in human œsophagus while still attached—free surface seen with papillæ—magnified 32 diameters.

Fig. 2. Epithelium removed and viewed on opaque ground—the internal surface with openings for admission of papillæ—magnified 32 diameters.

Fig. 3. Papillæ of human œsophagus, magnified 120 diameters.

Fig. 4. Epithelium in œsophagus of horse detached and viewed by transmitted light—the dark specks seen corresponding to the papillæ—magnified 32 diameters.

Fig. 5. Cribriform membrane lying beneath epithelium in horse, viewed by transmitted light—the foramina give passage to the papillæ—magnified 32 diameters.

Fig. 6. Papillæ in œsophagus of horse, viewed on opaque ground —magnified 32 diameters.

Fig. 7. Cells of human stomach, some of them partially fringed by prolongations of the mucous membrane—magnified 32 diameters.

Fig. 8. Cells of human stomach—open mouths of tubes seen at the bottom of each,—magnified 32 diameters.

PLATE II.

Fig. 1. Portion of cardiac extremity of human stomach—the tubes extremely short, and scattered over the mucous membrane—the honeycomb structure very imperfect, a few cells only being formed—magnified 30 diameters.

Fig. 2. Cells in cardiac portion of stomach of pig, magnified 16 diameters.

Fig. 3. Section of a portion of mucous membrane from stomach of pig—the fibres, which are tubular, seen running perpen-

dicularly to the surface, and forming the thickness of the membrane—magnified 16 diameters.

Fig. 4. Cells in stomach of pig, with mouth of tubes opening into them—magnified 32 diameters.

Fig. 5. Section of mucous membrane of stomach in pig after being injected—*a*, cellular tissue to which the tubes are attached, and in which the capillaries form a plexus—*b*, free extremity of the tubes — *c*, *d*, two tubes into which the injection has burst—magnified about 20 diameters.

Fig. 6. Pyloric glands in stomach of a girl who died suddenly when apparently in good health—natural size.

Fig. 7. Section of a portion of gastric gland from water-hen, showing part of internal surface and tubular structure of its parietes—magnified about 40 diameters.

Fig. 8. Section of gastric gland of goose, showing fibrous structure of parietes and cells of internal surface—magnified 10 diameters.

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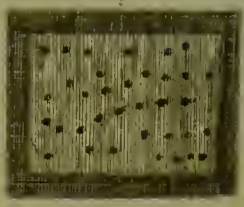

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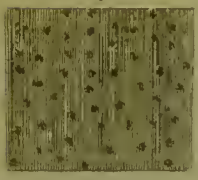

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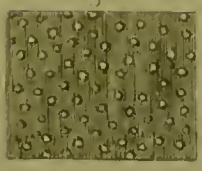

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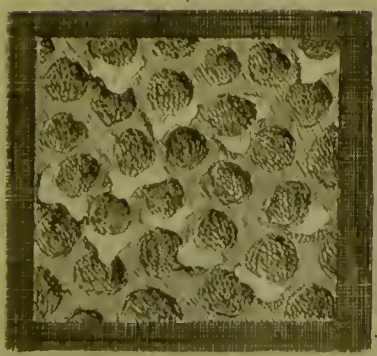

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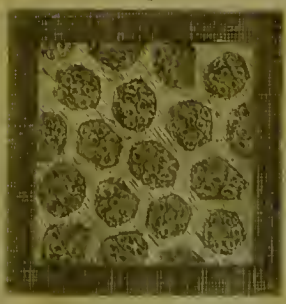

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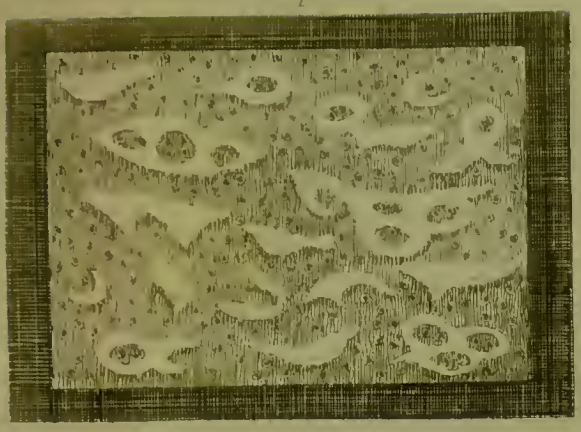

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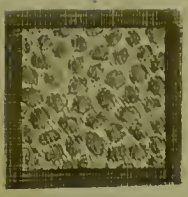

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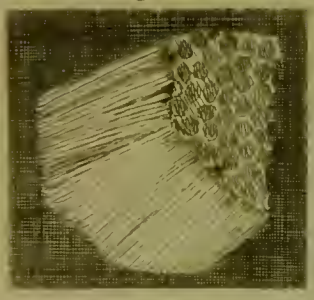

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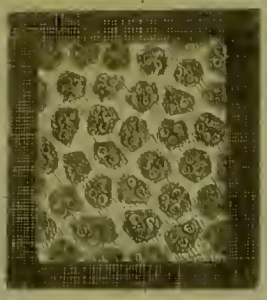

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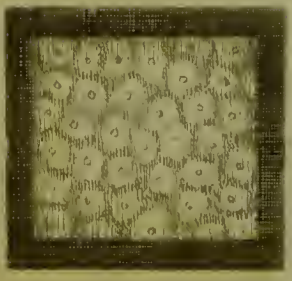

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